

TITLE OF THE INVENTION

Axial-flow thermal turbomachine

5

BACKGROUND OF THE INVENTIONField of the invention

10 The invention deals with the field of power plant technology. It relates to an axial-flow thermal turbomachine in accordance with the preamble of patent claim 1, which has a reduced rotor weight compared to the known prior art.

15 Discussion of Background

Thermal turbomachines, e.g. high-pressure compressors for gas turbines or turbines, substantially comprise a rotor fitted with rotor blades and a stator, in which
20 guide vanes are mounted. The rotor blades and guide vanes each have a main blade section and a blade root. To enable the blades and vanes to be secured to the rotor or in the stator, grooves are formed in the stator and on the rotor shaft. The roots of the guide
25 vanes and rotor blades are pushed into these grooves and then held in place.

The stationary guide vanes serve the purpose of diverting the flow of the gaseous medium which is to be
30 compressed or expanded onto the rotating rotor blades in such a way that the energy is converted with optimum efficiency.

It is known to produce blades and vanes integrally from
35 a single material, e.g. from stainless steel for gas turbine compressors or from a nickel-base superalloy for gas turbines and to use these identical blades or vanes to produce a row of blades or vanes. Blades or

vanes of this type are referred to below as conventional blades.

5 For certain applications, the mean mass of a row of blades is limited by the load-bearing capacity of the rotor.

10 Therefore, there are known solutions for producing blades in a hybrid form. In the case of the hybrid form, different materials with different physical properties are combined with one another to produce a blade in order to obtain an optimum blade design. For example, a hybrid rotor blade for an engine, in which the trailing edge of the main blade section, which has
15 only an aerodynamic function, is made of a lightweight material, preferably a fiber composite material, e.g. carbon fiber composite material, is known from DE 101 10 102 A1. A (lightweight) trailing edge of this type advantageously makes it possible to reduce the
20 weight of the blade. The two parts of the main blade section (heavy metallic leading edge and lightweight trailing edge made of fiber composite material) are joined by adhesive bonding or riveting.

25 A similar solution is described in WO 99/27234, which discloses a rotor with integral blading, in particular for an engine, on the circumference of which rotor blades are arranged, the rotor blades, in order to reduce vibrations, having a metallic blade root, a
30 metallic main blade section, which forms at least part of the blade leading edge and of the adjoining region of the blade surface, and a main blade section made of fiber-reinforced plastic. In this case too, the main blade section made of plastic is secured to the
35 metallic part of the main blade section by adhesive bonding/riveting or by means of a clamp fit.

This known prior art has the drawbacks listed below. Firstly, the abovementioned forms of attachment are unable to withstand high loads over the course of a prolonged period of time, and secondly the
5 fiber-reinforced plastics can only be used in certain temperature ranges, and consequently these known technical solutions are only suitable in particular for engine technology. Moreover, the characteristics of the main blade section (mechanical properties, resistance
10 to oxidation, frictional properties) are altered compared to those of the main blade sections which consist of a single material, and this can have an adverse effect on the operating performance of the engine.

15 Furthermore, EP 0 513 407 B1 has disclosed a turbine blade made of an alloy based on a dopant-containing gamma-titanium aluminide, which comprises main blade section, blade root and if appropriate blade covering
20 strip. During production of this blade, the casting is partially heat-treated and hot-formed in such a manner that the main blade section then has a coarse-grained structure, which leads to a high tensile strength and creep rupture strength, and that the blade root and/or
25 the blade cover strip has a fine-grain structure, which leads to an increased ductility compared to the main blade section.

Although the use of these blades consisting of gamma-
30 titanium aluminide advantageously reduces the mass of the rotor compared to conventional blades, a drawback of this prior art is that the blade tips, on account of their brittleness, flake off when they come into contact with the stator during operation. However, it
35 is not normally possible to prevent this friction.

Experience gained with steel blades in high-pressure compressors has shown that even with what are known as

abradable layers on the stator, the blade tips of the rotor blades can become ground down while the compressor is operating. This entails a considerable frictional force, which leads to brittle blade fracture
5 if the blade is not ductile.

SUMMARY OF THE INVENTION

Accordingly, one object of the invention is to avoid
10 the abovementioned drawbacks of the prior art. The invention is based on the object of developing a thermal turbomachine which is distinguished, on the one hand, by a reduced overall weight of the rotor and in which, on the other hand, brittle blade fracture is
15 prevented, so that the service life of the turbomachine is extended.

According to the invention, this object is achieved, in the case of a thermal turbomachine in accordance with
20 the preamble of patent claim 1, by virtue of the fact that at least two blades which are at a uniform distance from one another and are made of a more ductile material are arranged in a row of blades between the intermetallic blades, the blades made of
25 the more ductile material either being considerably longer than the intermetallic blades or, if they are of the same length, having a different blade tip shape than the intermetallic blades.

30 The advantages of the invention consist in the fact that firstly the weight of the rotor is reduced by the use of the blades made of intermetallic compounds, which leads to an increase in the service life of the rotor/blade connection, and secondly the brittleness of
35 the intermetallic blades does not entail any increased risk when the turbomachine is operating, since the blades made of the more ductile material arranged in

the same row of blades absorb the frictional/wearing forces.

5 It is expedient, if, in addition, intermediate pieces made of a more lightweight material than the rotor material, preferably an intermetallic compound or a titanium alloy, are additionally arranged in the rotor between the rotor blades of a row of blades. In this way, the weight of the rotor is additionally reduced.

10 Furthermore, it is advantageous if the intermetallic blades and the intermediate pieces consist of an intermetallic γ -TiAl compound or an intermetallic orthorhombic TiAl compound, since this use of materials
15 in accordance with the invention leads to a considerable reduction in the weight of the rotor. The relative density of the intermetallic titanium aluminide compounds is, for example, only approximately 50% of the density of stainless Cr-Ni-W steel.

20 Finally, it is advantageous if the blade tips are coated with a hard phase or a wear-resistant layer is applied by means of laser welding, in order to prevent the blade tips from being ground down and/or to reduce
25 the frictional force.

BRIEF DESCRIPTION OF THE DRAWINGS

30 A more complete appreciation of the invention and many of the attendant advantages thereof will be readily obtained as the same becomes better understood by reference to the following detailed description when considered in connection with the accompanying drawings, wherein:

35 fig. 1 shows a cross section through a row of rotor blades belonging to a diagrammatically depicted

high-pressure compressor according to the invention in a first variant embodiment;
fig. 2 shows a detail of a second variant embodiment of the invention, in which intermediate pieces made of intermetallic compounds are arranged in the rotor between the rotor blades, and
fig. 3 shows a TiAl blade with a coated blade tip as a third variant embodiment of the invention.

10 DESCRIPTION OF THE PREFERRED EMBODIMENTS

Referring now to the drawings, wherein like reference numerals designate identical or corresponding parts throughout the several views, fig. 1 shows a cross section through a diagrammatically depicted row of rotor blades belonging to a rotor 1 for a high-pressure compressor of a gas turbine. The rotor 1 is surrounded by a stator 2. Rotor blades 3, 3' are mounted in a circumferential groove in the rotor 1, while guide vanes (not shown here) are secured in the stator 2. The blades 3, 3' are, for example, exposed to a pressure of approx. 32 bar and a temperature of approx. 600°C for several thousand hours.

25 According to the invention, the row of blades illustrated is fitted with two different types of rotor blades 3, 3'. To reduce the weight, the majority of the rotor blades, namely the rotor blades 3, are made of an intermetallic compound, preferably a γ -titanium
30 aluminide compound. The rotor blades 3', by contrast, are made of a material, for example a stainless Cr-Ni steel, which is more ductile than the material of the rotor blades 3. At least two more ductile blades 3 of this type, which are at a uniform distance from one
35 another (in Fig. 1, there are four such blades in this exemplary embodiment), are arranged in the row of blades comprising the intermetallic blades 3. In this exemplary embodiment, the blades 3' made of the more

ductile material are significantly longer than the intermetallic blades 3, i.e. in the event of undesirable contact between the blades and the stator during operation, these more ductile blades can absorb
5 the frictional forces without any brittle fracture occurring. In another variant embodiment, it is also possible, in order to achieve the same effect, for both types of blades 3, 3' to be of the same length, but to have different shapes of blade tip 5, for example for
10 the more ductile blades 3' advantageously to have truncated or blunted blade tips 5.

In the present exemplary embodiment, the rotor blades 3' consist of a stainless steel of the following
15 chemical composition (in % by weight): 0.12 C, < 0.8 Si, < 1.0 Mn, 17 Cr, 14.5 Ni, < 0.5 Mo, 3.3 W, < 1 Ti, < 0.045 P, < 0.03 S, remainder Fe. The shaft of the rotor 1 likewise consists of steel. The density of steel is known to be approx. 7.9 g/cm³. The
20 intermetallic compound of which the rotor blades 3 are made has the following chemical composition (in % by weight): Ti-(30.5-31.5)Al-(8.9-9.5)W-(0.3-0.4)Si. The density of this alloy is advantageously only 4 g/cm³, and consequently the rotor 1 according to the invention
25 is significantly more lightweight than a rotor comprising exclusively conventional steel blades.

Fig. 2 shows a detailed illustration of a further exemplary embodiment of the invention. The weight of
30 the rotor 1 can be additionally reduced if - as illustrated in Fig. 2 - intermediate pieces 4 made of an intermetallic compound, in this case of a γ -titanium aluminide compound, are mounted in the circumferential groove in the rotor 1 between two adjacent rotor blades
35 of a row of blades belonging to the rotor 1.

The intermetallic compound used to produce the intermediate pieces 4 has the same chemical composition

The intermetallic compound used to produce the intermediate pieces 4 has the same chemical composition as the compound which is used for the blades 3 and is described above.

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Intermetallic compounds of titanium with aluminum have a number of advantageous properties which makes them appear attractive as structural materials in the medium and relatively high temperature ranges. These include their lower density compared to superalloys and compared to stainless steels. However, their brittleness is often an obstacle to their technical use in their current form.

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15 The above-described intermetallic γ -titanium aluminide compound is distinguished by a density which is approximately 50% lower than that of the steel used for the rotor 1 and the blades 3' in this exemplary embodiment. Furthermore, it has a modulus of elasticity at room temperature of 171 GPa and a thermal conductivity λ of 24 W/mK.

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Table 1 compares the physical properties of the two alloys.

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	Density in g/cm ³	Coefficient of thermal expansion in K ⁻¹
γ -Ti-Al	4	10×10^{-6}
Stainless steel	7.9	18.6×10^{-6}

Table 1: physical properties of the various materials

Since the rotating components of the high-pressure compressor of a gas turbine installation are subject to high thermal loads at temperatures of up to approx. 600°C, the reduction in the weight of the rotor 1 according to the invention has the advantageous

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turbomachine. The stresses in the blade root fixing in the rotor 1 are reduced.

The intermetallic blades 3 and the intermediate pieces 4 are produced in a known way by casting, hot isostatic pressing and heat treatment with minimal remachining.

Fig. 3 shows a further preferred variant embodiment. This figure illustrates a rotor blade 3 with a coated blade tip 5. The blade tip may be coated with a hard phase, or alternatively a wear-resistant layer may be applied by means of laser welding. In both cases, the blade tips are prevented from being ground down and/or the frictional force is reduced.

Of course, the invention is not restricted to the exemplary embodiments illustrated.

For example, it is also possible for an orthorhombic titanium aluminide alloy with a density of 4.55 g/cm^3 to be used as material for the intermetallic blades 3 and/or the intermediate pieces 4. Orthorhombic titanium aluminide alloys are based on the ordered compound Ti_2AlNb and have the following chemical composition (in % by weight): Ti-(22-27)Al-(21-27)Nb.

The intermediate pieces 4 may also be made of a less expensive titanium alloy rather than an intermetallic γ -titanium aluminide compound, although in this case the weight reduction is not as great.

Furthermore, it is conceivable for the invention to be used not only for high-pressure compressor rotors but also for turbine rotors with turbine blades made of known turbine steel, heat-resistant steel or of a superalloy, for example a nickel-based superalloy, in which the intermediate pieces between the rotor blades consist, for example, of an intermetallic γ -titanium

consist, for example, of an intermetallic γ -titanium
aluminide alloy or an intermetallic orthorhombic
titanium aluminide alloy. This too advantageously makes
it possible to achieve reductions in weight and an
5 increase in the service life of the turbomachine.

The brittleness of the intermetallic Ti-Al alloys has
no adverse effect for the use of these materials in
accordance with the invention as described above,
10 since, when used as intermediate pieces, they are not
exposed to any abrasive contact or frictional wear, and
when used as blades the corresponding more ductile
blades absorb the frictional/wearing forces.

15 Obviously, numerous modifications and variations of the
present invention are possible in light of the above
teachings. It is therefore to be understood that within
the scope of the appended claims, the invention may be
practiced otherwise than as specifically described
20 herein.

LIST OF DESIGNATIONS

- | | |
|-------|--------------------|
| 1 | Rotor |
| 2 | Stator |
| 3, 3' | Rotor blade |
| 4 | Intermediate piece |
| 5 | Blade tip |